PRICE

Back-Filling of Trenches

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BACK-FILLING OF TRENCHES

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

HUGH MITCHEL PRICE

ENTITLED BACK-FILLING OF TRENCHES

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Civil Engineering.

Ira O. Baker

HEAD OF DEPARTMENT OF Civil Engineering.

I

I N T R O D U C T I O N

Probably one of the most important subjects to be considered in street improvement and one that is generally neglected, is the back-filling of trenches. In this statement the term street improvement includes not only the laying of some form of pavement, but also the construction of water mains, sewers, conduits and all such public conveniences. In the construction of the last mentioned utilities, numerous trenches are excavated both longitudinally and transversely to the street, and over these re-filled trenches the pavement is to be laid at some future time. Hence the proper re-filling of trenches is an exceedingly important matter, for the life of a pavement determines its economy, and long life can be obtained only with a good foundation. In order to secure a good foundation all trenches over which the pavement is to be laid, must be filled in such a manner as to secure a degree of compactness equal to that of the surrounding soil. While the importance of this is generally known, the condition is seldom secured. It is very common to see a depression 2 or 3 inches deep traversing the entire length of the street, caused by the settlement of an improperly filled trench. These depressions are not only unsightly, but many times they amount to holes of some depth into which a horse or pedestrian may step, thus laying the city liable to damages. The cause of this defect in any particular case is hard to determine, but it is safe to say that those cities that neglect the proper re-filling of trenches from a mistaken sense of economy, are penny wise and pound foolish.

While it is well known that engineers appreciate the importance

of the proper treatment of trenches, it is equally well known that the city councils are very backward in appropriating the money for such work, thereby handicapping the engineer and securing inferior results. Probably this lack of funds is responsible for the inadequate specifications regarding the back-filling of trenches to be found in many of the smaller cities. If this subject is touched upon at all in the specifications, only one or two methods are specified, and they very obscurely, leaving the choice of the method to the engineer. It is seldom if ever found that specifications designate different methods of back-filling for different kinds of earth, or take into consideration whether the pavement is to be laid in two years or two months, thus necessitating a new interpretation of the same specifications for every new condition that may arise. In consequence of the obscurity in specifications and the difference in the opinions of the engineers in charge of the work, but very little reliable data on the best method of re-filling trenches can be found; and hence it is not strange that specifications for such work in cities having widely different conditions are very similar. Knowing the general need of definite data on the subject, the writer has in the following pages endeavored to state clearly the opinions of such engineers as have investigated the matter and also to present the results of personal experiments.

The following discussion is divided into two parts: Part I, The Opinions of Others; Part II, The Results of Experiments and Experience of the Writer.

PART I.

EXPERIENCE OF OTHERS.

This part is divided into two portions, the first a summary of the subject and the second the opinions of engineers consulted by the writer.

The only literature on this subject that the writer could find was as follows:

1. Two articles in the March, 1897, Report of the New England Water Works Association by Mr. E. A. Hammatt and Mr. Bowing, of Boston, together with a discussion of the same by members of the Association.

2. A discussion of the methods of Filling Trenches in Baker's Roads and Pavements.

3. Specifications for Back-Filling in Folwell's Sewerage.

4. A series of open letters in the Engineering News of Oct. 31, '95 and Aug. 22, '96.

1. REPORT OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

All the work reported upon in the above article was executed in the New England States, hence allowance must be made for the difference in both soil and the original condition of the road in which the trench was placed. In most of the New England States not only are the streets of the cities and towns macadamised but also the roads in the rural districts as well are so treated. In consequence of this the necessity of leaving the street in a level and smooth condition is greater than in the dirt streets of our western cities. For this reason it will be noted that the gentlemen hereinafter quoted often refer to the re-placing of the re-surfacing material, a condition which in the majority of cases will not confront

the western engineer.

Mr. Hammatt's Views. The following is a summary of Mr. Hammatt's article:

Trenches should not be re-filled loosely and crowned for the following reasons. First, the street is left in an unsightly and often dangerous condition and can hardly be used for traffic without practically re-surfacing. Second, any settlement that occurs will be in the center of the trench thus leaving two shoulders or ridges where the earth was placed on the original surface at the sides of the trench. These shoulders prevent proper drainage of the street as well as of the trench, and will have to be removed subsequently. Third, if by accident a large part of the original road surfacing material does not get carted away as surplus, it is placed in these ridges and in the crowning of the trench, and gets carried off when the shoulders are removed.

As a remedy for these evils, Mr. Hammatt suggests that all the material excavated be put back, which can be done if the pipe placed in the trench is not too large. In support of the efficiency of this remedy he quotes from some unknown authority the following data regarding the shrinkage of various earths.

Gravelly earth..... 8%

Yellow clayey earth..... 10%

Light sandy earth..... 15%

Puddled clay..... 25%

"If this is correct", he says, "we should have in a trench 5 Ft. deep and 2.5 Ft. wide, giving 12.5 Cubic Ft. per running foot, a shrinkage in case of:

Gravelly earth equivalent to a depth of 0.4 Ft. or 1.00 cubic ft.

Yellow clayey earth equivalent to a depth of 0.5 ft. or 1.3[illegible] cu. ft.

Light sandy earth " " " " 0.8 " " 1.50 " "

Puddled clay " " " " 1.3[illegible] " " [illegible].1[illegible] " "

From the above data Mr.Hammatt concludes that when pipe is laid not larger than 12 inches, all the excavated material can be put back without leaving a ridge and that even with a 16-inch pipe but little surplus would be left, about 140 cu. yds. per mile or 2.6 cu. yds. per 100 ft. This would also indicate that for pipe 8 inches in diameter all the earth should be replaced and leave about 4 inches of depth to be filled by borrowed material.

In order that all the earth be returned to the trench Mr.Hammatt advocates a liberal use of water rather than entire dependence upon the rammer, at least in its present form. As a more serviceable form of rammer he suggests that one of 8 or 10 sq. in. be substituted for the more general one of 25 lbs. with 29 sq. in. of surface. In support of the lighter tamper Mr.Hammatt says that the workmen will lift it higher and strike a harder blow with less expenditure of energy than with the larger one. In ramming with this tool, the layers should not be more than 4 inches in thickness. (*)

In the discussion following Mr.Hammatt's paper several opinions were expressed, all agreeing pretty generally with Mr.Hammatt's views regarding the liberal use of water and the small tamper. Mr.Winslow, however, described a method of flushing a trench that is at least novel. In Cambridge, Mass., a 48-inch main was placed in a trench averaging about 1[illegible].5 feet in depth. This trench was filled with sandy material

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(*) For a discussion of this point by the writer of this thesis see page 18.

to within about a foot of the surface and then flushed by inserting the nozzle of a fire hose in the loose material to within a foot or two of the pipe. The stream was allowed to play in one place until the ground was thoroughly saturated, and was then moved some 4 or 5 ft. and the same thing repeated.. The trench when puddled was then filled the remainder of the way by tamping, and fairly well crowned off with a top material. A few days later a steam roller was put over this crown leaving the street in nearly as good condition as originally. Whether or not settlement occurred afterwards is not known. The cost of water in this case was under $800.00.

Mr. E. A. Taylor told of the use of a road machine for filling trenches where settlement was of no consequence. The material was scraped in and crowned pretty well and the trench left until after the first rain. The machine was again run over the trench and this was repeated until serious settlement stopped.

Mr. Bowing's Views. The following are Mr. Bowing's views in brief: One item and a very important one that cannot be left out of consideration is the cost of executing back-filling so as to prevent settlement. The fact that earth can be put back into the trench in such a manner that no settlement will occur can hardly be disputed; but whether or not it will pay so to do is another question. There is no question that back-filling in paved streets should be done in the best possible manner, but in the case of country roads or streets of smaller towns this is a needless expense, with the exception of trenches across the street, in which case the work should be more carefully done. Mr. Bowing says that the cost of executing back-filling so as to insure non-settlement is about $100.00 to $150.00 per mile in excess of that in

which no ramming was required. Therefore Mr. Bowing suggests that engineers and others having the execution of such work in charge carefully consider the economic side and write the specifications accordingly, and then execute the work strictly according to specifications. Regarding methods Mr. Bowing said very little and agreed with views already expressed in this article. He recommends the use of a tool for tamping around large pipe, substantially of the form shown in Fig. 1.

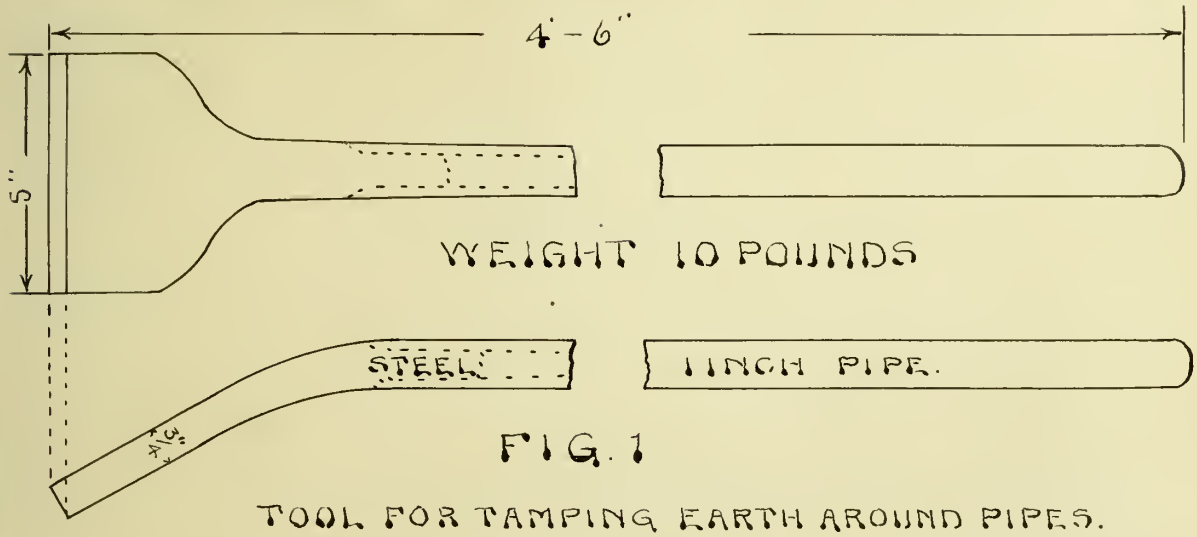

FIG. 1

TOOL FOR TAMPING EARTH AROUND PIPES.

In the discussion that followed the reading of Mr. Bowing's paper the opinions of the members agreed with his respecting the preparation of specifications and the subsequent execution of the work, and some suggestions were offered as to the methods of back-filling. Mr. Beals agreed with Mr. Bowing regarding the use of the rammer mentioned and said that he had found by experience that if a good bond was obtained between the sides of the trench and the filling, settlement was not so likely to occur as when the material was put in with a heavy tamper. If a bond is not obtained, the back-filling in settling shrinks leaving a crack on each side of the trench into which water may gain access

thus causing the trench to settle.

With respect to crowning, the consensus of opinion seemed to be in favor of a very slight crown over the trench. Mr. Hammatt, in support of little or no crown maintained that the expense of carting away material due to the excessive crown was more than that incurred in filling up a slight depression.

3. BAKER'S ROADS AND PAVEMENTS.

Professor Baker's views as expressed in his treatment of this subject in his Roads and Pavements coincide in some respects with opinions already expressed in this article, but differs as to the use of water in back-filling. He says that "there is no question that the proper re-filling of service trenches both in paved and unpaved streets is a matter of importance, and should be as rigorously inspected as any branch of municipal work. In many cases the damage done to expensive pavements by improper back-filling would more than pay the cost of proper re-filling". He goes on to state that the practice of filling the trench with loose material and trusting to the action of the elements to cause settlement will seldom if ever prove either efficient or economical, and should never be used if a pavement is to be laid in the street in a comparatively short time.

In connection with the use of water as a means of back-filling Professor Baker says water should be used only where the material is such that it can be readily broken down by such means, for example, sand or sandy soil, and where water is cheap. The back-filling should be placed in the trench in layers not to exceed 8 or 10 inches, and then be played upon by a stream having force enough to wash the smaller particles into the interstices. The use of water, however, is seldom

cheaper than tamping, and in general will not give as good results. In clayey or impervious material water should not be used on account of the shrinkage occasioned by the drying of the back-filling.

In the opinion of Professor Baker back-filling in all cases except in sand and gravel can be more thoroughly done by tamping. To obtain the best results the material should contain moisture enough to be plastic, should be deposited in layers 3 or 4 inches in depth, and should be thoroughly tamped. The amount of the tamping will vary with the material and its condition. Respecting the kind of tamper to be used Professor Baker advocates the use of a 5 or 6 pound tamper instead of a 25 or 30 pound now in use, arguing that a harder blow can be struck with less fatigue with the lighter tamper than with the heavier one.

Regarding the replacing of all the material in the trench Professor Baker says that in may cases this will give fair results but with exceedingly large or very small pipe dependence can not be placed upon this method. With very large pipe it would be impossible to replace all the material, while with very small pipe the material could be replaced and more, necessitating borrowing, if the back filling was properly tamped. "Therefore", Professor Baker says, "the specifications to replace all the material must have a careful and intelligent supervision to insure good results".

In the matter of re-filling with material other than that taken from the trench Professor Baker says it has been proposed to use sand as a back-filling material but knows of no case where it was actually employed.

In at least a few cases he says concrete has been used to re-fill the trench, but in the majority of cases the cost would be prohibitive.

3. FOLWELL'S SEWERAGE.

Professor Folwell in his work on Sewerage treats the subject only in the form of specifications for the proper ~~of the~~ execution of the back-filling. The writer takes it for granted that Professor Folwell's views are represented by his specifications of which the following is the substance.

To re-fill a sewer trench (This would also apply to conduit and water trenches) loose fine earth should be rammed in 6-inch layers to a depth of 2 feet over the pipe, the remainder being tamped in 9-inch layers. The material used should not contain over one third broken rock, and should contain no stones exceeding fifty pounds in weight. If the trench is to be overlaid with a pavement, and settlement is to be prevented entirely, Professor Folwell specifies that the earth shall be spread in 4-inch layers and be compacted with a 4 to 8-pound rammer having a surface not exceeding 20 sq. in. He further specifies that there shall be at least two rammers to every shoveller and that all shall be of equal efficiency. Professor Folwell specifies a half-inch crown over the trench.

Concerning the item of water tamping, as he calls it, known elsewhere in this article as flushing, Professor Folwell says that the earth shall be deposited in 3-foot layers and be flushed to the extent that water will just show upon the surface after standing 5 minutes. This shall be continued to within 2 feet of the surface when the trench shall be allowed to stand a few hours, the remaining 2 feet being tamped.

In the matter of re-placing all the material, Professor Folwell says that it can be done when the diameter of the sewer does not exceed one-sixth of the depth of the trench.

Professor Folwell places the cost of re-filling to be from 4 to 1[illegible] per cu. yd.

4. ENGINEERING NEWS.

In the Engineering News for Aug. 23, '93, Mr. Fremont Hill, of Chicago, publishes an open letter advocating the use of sand as a material for back-filling. He urges that after the pipes are laid, the trench should be filled with thoroughly puddled sand, thereby compactly and completely filling the trench and leaving it ready for the street pavement at once. He admits that the substitution of sand for the excavated material would cost slightly more, but claims that the saving in the pavement would more than justify this expenditure.

In the same number of the Engineering News Mr. Whitney says that sand should be deposited in 1-foot layers and be flushed with a nozzle; and that clay should be tamped plastic, since flushing prevents its consolidation.

In the Engineering News of Oct. 31, '95, Mr. Eugene Lentilhon has the following letter:- In back-filling trenches as much of the material as possible is replaced in thoroughly rammed layers to within 3 feet of the surface. The remaining 3 feet is filled with thoroughly compacted sand, gravel, and asphalt and crowned off with a half-inch crown. Mr. Lentilhon says that he has never been able to replace all the material excavated as the material in which he worked was made-land containing considerable stone and brick. He further states that the crown left over the trenches disappeared under the action of traffic.

PART II

EXPERIMENTS BY THE AUTHOR

In consideration of the fact that there are little or no reliable data to found upon the subject of back-filling trenches, the writer in collaboration with Mr.F.B.Ingersoll performed a series of experiments to determine, if possible, the best methods to be employed in securing non-settlement of trenches after refilling. In performing the experiments every effort was made to ascertain the most practical method of properly refilling with the material encountered. With this end in view a number of specimen trenches 6 x 2 x 4 1/2 feet were excavated and re-filled by various methods. The work was done in the fall in order that the re-filled trenches might be subjected to the action of frost during the following winter and give time for settlement to take place. These trenches were inspected at frequent intervals and an accurate record taken of any change that occurred. The experimental trenches were excavated upon private property and for that reason were not subjected to the action of traffic as would be the case in a street. On account of this fact the writer [illegible] that these trenches in all probability reached final settlement at the end of six months—when the last inspection was made. On the other hand trenches re-filled in the same manner and subjected to the action of traffic would [illegible] require much more time on account of the formation of a crust over the trench that would support the loads temporarily.

Two methods of re-filling were employed, viz.: Tamping and Flushing.

Tamping. A trench 2 feet wide and 4 1/2 feet deep was excavated in the black prairie soil near the University. There was no loose

vegetable matter and almost no clay in this trench. The work was done in the fall and the soil was moderately dry for this season of the year. Immediately after opening the trench it was re-filled in layers 3 to 4 inches thick, each layer being thoroughly tamped with a wooden rammer having a face 6 x 8 inches and weighing 13 pounds. The trench was inspected at frequent intervals for six months, records being made of the existing conditions at each inspection. The trench was in private property and was not subject to the action of traffic. No settlement took place in six months.

A second trench of the same size as the preceding one was excavated near the first, the only difference in the two being that the lower 2 feet of the second trench was in clay. The excavated material was a little damper than that in the preceding case. The soil had about the consistency of moulding sand, i.e., if squeezed in the hand the mass would retain its form, and if this mass were held between the finger and thumb and shaken up and down with considerable force it would not be broken to pieces. A little more water caused the soil to become so sticky that it adhered to the face of the tamper to such an extent that much time was lost in cleaning the tool. The earth was tamped back the same as in the preceding case. At the end of six months no settlement had taken place, in fact it required some care to discover the boundaries of the trench.

Flushing. Flushing was employed in three slightly different ways. All of the trenches filled by this method closely adjoined the preceding one, and extended about 2 feet into the yellow clay.

The first method of flushing was to allow the earth to drop through 6 or 8 inches of water. The soil was finely divided, none of it being in large lumps, and the surface was always covered with water. The

work was done moderately slowly. At the end of six months the settlement was 3 per cent.

The second method of flushing consisted in depositing 6 or 8 inches of earth and covering it with water. The water was allowed to flow gently into the trench through an open garden-hose. When the surface of the water had risen above that of the earth, the water was allowed to subside and then another layer of earth was added. None of the earth fell through any depth of water. The earth was compacted entirely by the disintegrating action of practically still water. At the end of six months the settlement was about 1/2 inch or about 1 per cent.

The third method consisted in depositing the earth in layers as in the preceding case and then playing upon the material with a strong stream of water. The flushing was advanced from one end of the trench to the other and a new layer was added as the stream advanced. This method was very rapid with that particular material--loam. There was no settlement at the end of six months. It was found that the stream should have sufficient force to break up the large lumps of loam, say, a half a spade full.

From experience other than these experiments, the writer finds that the last method is not effective with stiff clay, since under the action of a strong fire stream the large lumps are broken up into smaller ones about the size of a man's fist, these small lumps resisting further disintegration and only being thrown and rolled from place to place by the continued action of the stream.

SUMMARY

From the foregoing results the writer concludes that in order to obtain satisfactory results the method of re-filling must be chosen

with reference to the material used as well as to the degree of settlement permissible.

Where absolute non-settlement is the essential feature regardless of cost, tamping is without doubt the method to employ in all cases except with sand and very wet loam. The earth should be as finely divided as possible and should be placed in the trench in layers not exceeding 6 inches in thickness. These layers should be thoroughly tamped with an iron tamper having a surface of about 16 square inches and weighing about 16 pounds. The tamper in general use weigns about 25 pounds and has a surface of about 28 square inches, which is too large and too heavy. The one used in the preceding experiments by the writer was too light and had too great a surface, while the tool recommended by Mr. Hammatt, see page 3 of this article, is too light and has too small a surface.

Flushing should be employed only when the material is either sand, loam or sandy-loam, and when a slight subsequent settlement is of no consequence and when water is very cheap. In using this method care must be taken to see that loam or material easily disintegrated is not deposited in a trench the sides of which are clay, more particularly blue-clay; for if this is done, the trench will be filled with soft mud which will settle greatly and not at all until the water has drained out of the trench which will require considerable time. Another requisite for successful flushing is that the stream must have sufficient force to break up all large lumps and wash the smaller particles into the interstices between the larger ones.

Where clay is met with and no settlement is desired, the only practical method seems to be tamping in layers. To obtain the best results

by this method, the clay should be moderately damp and in as small particles as possible.

In conclusion, since the subject is an important one, and since the foregoing experiments involved only a limited range of soils and conditions, the writer suggests that more extended experiments on the subject might be pursued with profit both to the investigator and to the profession.